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Arizona Geology

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THE STATE AGENCY FOR GEOLOGIC INFORMATION

MISSION

To collect and archive information about the geologic character, processes, hazards, and mineral and energy resources of Arizona and to inform, advise, and assist the public in order to foster understanding and prudent development of the State's land, water, mineral, and energy resources.

GOALS

- Increase understanding of the geology of areas with potential population growth and economic development
- Improve effectiveness of administering Arizona's oil and gas statutes
- Expand the customer base of the Arizona Geological Survey
- Improve access to digital geologic information to all users

Arizona Geology is published quarterly by the Arizona Geological Survey (AZGS), an Executive Branch agency of the State of Arizona, Jane Dee Hull, Governor. Please address comments, subscription requests, and address changes to the AZGS at 416 W. Congress St., Suite 100, Tucson, AZ 85701. Phone: (520) 770-3500.

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Energy Resources in Arizona

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Since World War II the population of Arizona and the United States has increased tremendously and has consumed large quantities of land, water, mineral, and energy resources. The Arizona Geological Survey summarized energy resources in Arizona about 10 years ago (Duncan and Mancini, 1990). Because new information about coal, oil, and gas has been published since then, an up-dated summary is provided on the following pages.

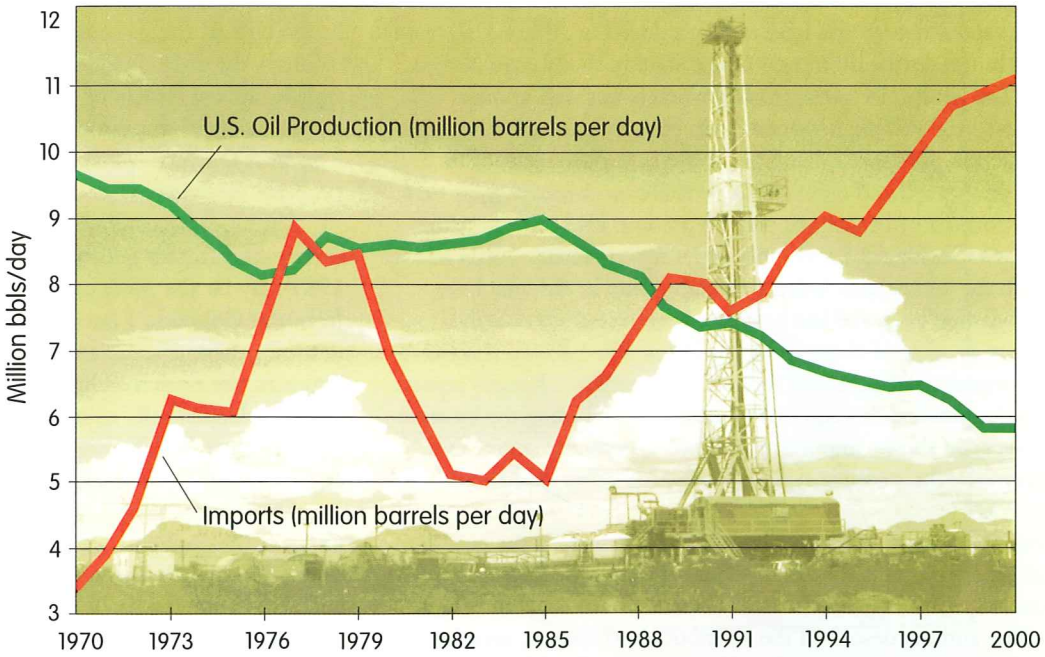

Figure 1. *Graph showing the relationship between oil production in the United States and the amount of oil imported by the United States.*

Arizonans, like other Americans, are energy consumers. They depend on electricity generated by power plants that use coal, oil, natural gas, hydropower, and nuclear power. Nineteen such facilities are currently operating in Arizona. Energy shortages in California have caused a ripple effect in Arizona. Applications for twenty new power plants have been approved or are being reviewed by the Arizona Corporation Commission. These new plants, assuming all of them will be approved, will generate far more electricity than will be needed to meet Arizona's demand. They will also consume tremendous quantities of Arizona's precious ground water.

Automobiles, trucks, buses, trains, aircraft, farm equipment, and other motorized vehicles are powered by gasoline, diesel, and jet fuel, which are the refined products of crude oil pumped from wells. Consumption of oil and gas in the United States has increased but domestic production has declined (Figure 1). Prior to the 1973 oil embargo by the Organization of Petroleum Exporting Countries, the U.S. imported 30 percent of the oil it consumed. Today it imports 60 percent.

Arizona has oil, natural gas, coal, and uranium resources, as well as geothermal energy. The State also has potential to use energy from the sun and wind. The potential for undiscovered resources is discussed below.

Oil and gas. Exploration for oil and gas in Arizona began in the early 1900s, but the first discovery was not made until 1954. Although other discoveries were made during the next 20 years, production of crude oil in Arizona peaked in 1968 and has been declining since. Natural gas production was in decline until 1989 when a new pipeline was constructed and additional wells were drilled. To date more than 20 million barrels of oil and 28 billion cubic feet of natural gas have been produced in Arizona, all from wells in the northeastern part of the state in the Navajo Nation.

The subsurface geology of Arizona is not well known because little drilling has been done. Past and current oil and gas production, shows of oil and gas in wells, surface seeps of tar and high gravity oil, and outcrops of petroliferous rocks suggest that undiscovered hydrocarbons may be present. Early this year the Arizona Geological Survey released a report (Rauzi, 2001) in which the author concluded that eight areas in Arizona have hydrocarbon potential but have not been tested adequately (Figure 2). One of those areas, the Black Mesa Basin, also has coal deposits and potential for coal-bed methane. Rauzi's report includes detailed descriptions of each area including the location of seeps, oil shows, important drill holes, potential source and reservoir rocks, possible types of traps, and other information.

Coal. Nations, Swift, and Haven (2001) described the geology and coal deposits within Black Mesa Basin on land owned by the Navajo Nation and Hopi Tribe in northeastern Arizona (Figure 3). The authors described the distribution, thickness, correlation, depth from the surface, and quality of coal beds within the Dakota, Toreva, and Wepo formations (Cretaceous age). They also analyzed 14 coal samples.

Two coal mines, the Kayenta and Black Mesa, are active. A train hauls coal from the Kayenta mine to the Navajo Generating Station near Page. Coal from the Black Mesa mine is transported through a slurry pipeline to the Mojave Power Plant on the Colorado River near Davis Dam in southern Nevada. Since 1975, 10 to 15,000,000 tons of coal have been produced annually from the mines on Black Mesa. Peabody Coal Company has an agreement with the Navajo Nation and the Hopi Tribe to mine the coal.

Peirce and Wilt (1970) estimated that the Black Mesa Basin contains about 21 billion short tons of coal, including 9.6 billion in the Dakota, 6 billion in the Toreva, and 5.65 billion in the Wepo formations. Haven (1997) calculated the original coal resources in the Wepo to be 4 billion short tons, but did not attempt to refine estimates for the Dakota or Toreva.

Much of the coal in the Black Mesa Basin is deeply buried and thick coal beds are not common. Because of this, only a small portion of the coal can be mined. Nations, Swift, and Haven (2001) concluded that if methane is associated with the more deeply buried coal and exploration is permitted, methane might provide a valuable source of energy for local use and possibly for commercial production.

Persons who wish to conduct geologic studies on the Navajo Nation must first apply for, and receive, a permit from the Navajo Nation Minerals Department, P.O. Box 1910, Window Rock, AZ 86515. Those who desire to conduct geologic investigations on the Hopi Reservation must receive permission from the Office of Mining and Mineral Resources, The Hopi Tribe, P.O. Box 123, Kykotsmovi, AZ 86039.

Uranium. More than 100 nuclear reactors generate electricity in the United States today. Three of them are at the Palo Verde facility west of Phoenix. Nuclear reactors are powered by controlled nuclear fission of uranium atoms. Nuclear fission, which takes place within uranium fuel rods in a reactor, gives off heat. The heat converts water to steam that drives turbines that generate electricity.

Uranium occurrences are known throughout the State in a variety of different geologic settings (Wenrich and others, 1989). By far the most uranium production, however, has been from the Colorado Plateau in northern Arizona. Some of the uranium there is associated with sandstone units. The richest deposits, the ones that have greatest potential today, occur in what geologists call "collapse-breccia pipes," or simply breccia pipes (Figure 3). The high grade of these deposits makes them attractive exploration targets.

During the geologic past, thousands of caverns developed in the Redwall Limestone due to dissolution by ground water. Eventually the roof rock above many of the caverns collapsed into the open caverns. After this process had run its course, thousands of cylindrical, vertical, pencil-shaped masses of fragmented rock (breccia pipes) had formed. A typical pipe is about 300 feet in diameter and may extend upward as many as 3,000 feet (Wenrich and others, 1989). As water

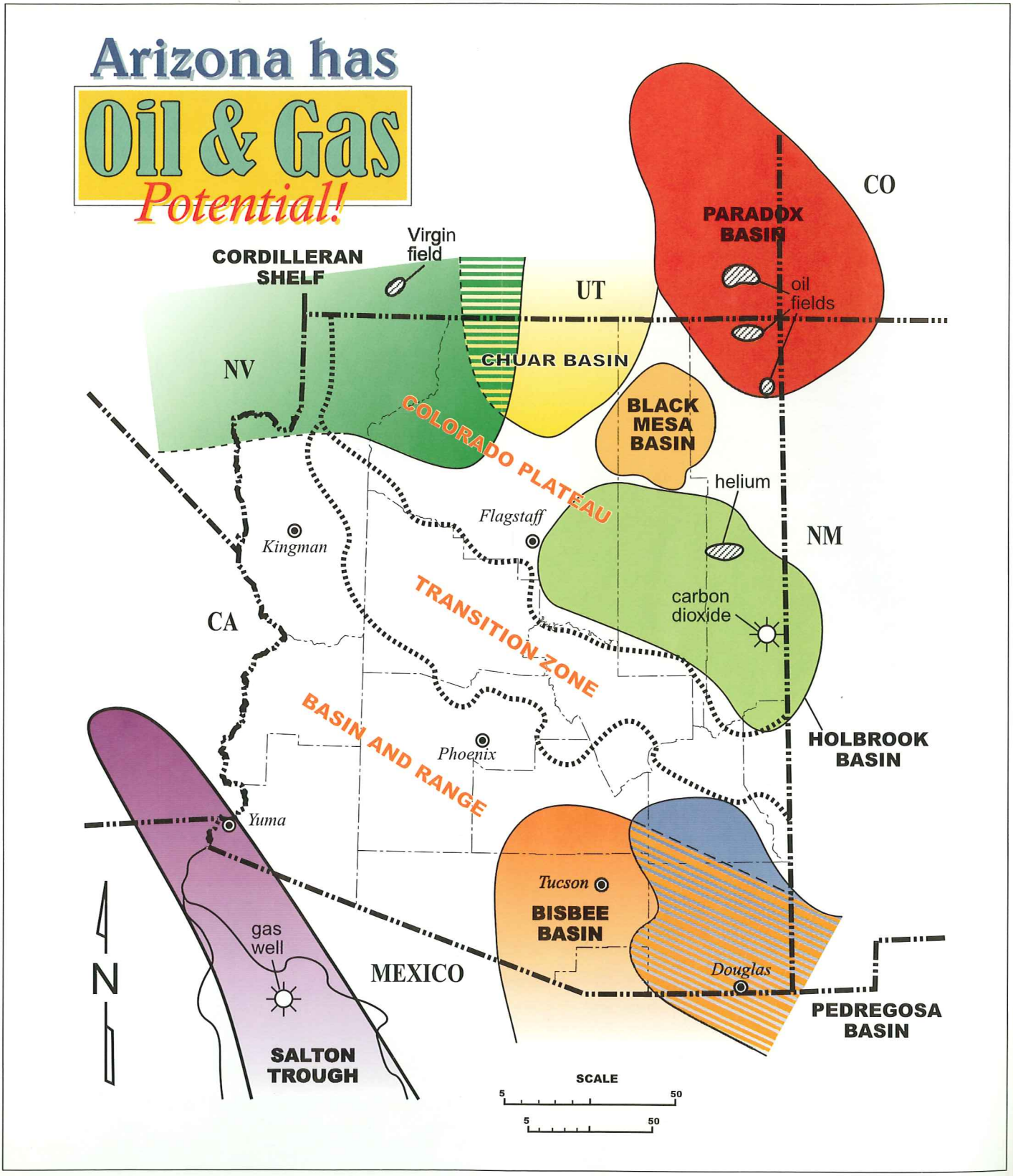

Figure 2. *Areas with oil and gas potential in Arizona are shown. Each of these areas is described in detail in Circular 29,* Arizona has oil and gas potential!

moved through the collapsed rock, salts and metals in solution in the water were deposited as minerals.

Although thousands of pipes are at or near the surface, only about one percent of them contain uranium ore bodies. By 1989, 13 uranium-ore-bearing breccia pipes had been identified. Wenrich and others (1989) concluded that at least 40 more pipes have excellent potential for development as orebodies.

Geothermal. Beginning in 1975, shortly after the oil embargo by the Organization of Petroleum Exporting Countries, Congress funded the U.S. Department of Energy to assess potential geothermal resources. A cooperative assessment project with the State of Arizona was undertaken from 1977-1982. Geologists who worked on this project prepared maps and reports that identified and described geothermal anomalies. Papers by Stone (1989), Stone and Witcher, (1982), and Witcher, Stone, and Hahman (1982) summarized the results of work completed in Arizona during the five-year project.

Potential geothermal resources in the low-to moderate-temperature range are abundant in southern Arizona (Figure 3), where most valleys have wells that produce warm to hot water. Stone (1989) discussed evidence for a potential geothermal resource east of San Francisco Mountain and in the White Mountain volcanic field, where geologically young volcanic eruptions have occurred.

Stone (1989) concluded that it is unlikely any vapor-dominated or many high-temperature hydrothermal geothermal systems will be found in Arizona. This is because most Arizona geothermal systems derive their heat from deep circulation of surface-derived water. High-temperature systems are commonly associated with still-hot, shallow-crustal magma chambers.

Last year the U.S. Department of Energy initiated GeoPowering the West to help increase the use of geothermal energy for electricity production, industrial process applications, and heating for commercial establishments and residences. This program, if successful, will reduce consumption of oil and natural gas.

Conclusions. Ample evidence suggests that Arizona may have undiscovered oil and gas resources. Coal deposits are currently being mined and may have associated methane gas. Potential for discovery of additional high-grade uranium deposits is excellent. Low- to moderate-temperature geothermal anomalies are common in southern Arizona and may be present beneath the Colorado Plateau. Additional exploration may lead to discovery and development of these resources. If so, this will be one small way to help alleviate the energy shortage and, at the same time, generate additional revenue for rural Arizona and the State.

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Coal, Uranium, and Geothermal Potential

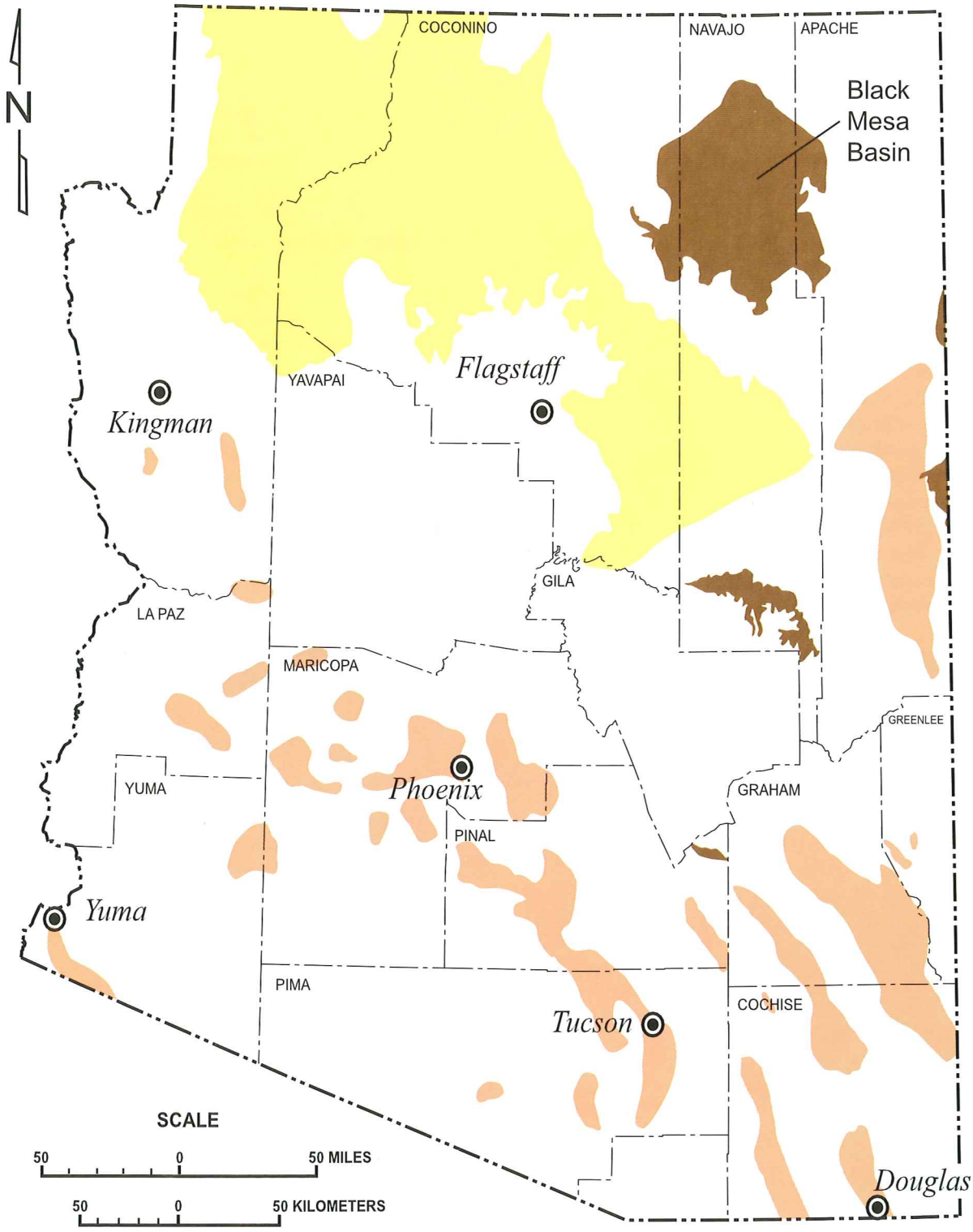

Figure 3. *Areas with coal deposits are shown in brown. Breccia-pipe uranium deposits may be present within the area shown in yellow. Orange-colored areas have low-to-moderate temperature ground water.*

NEW PUBLICATION

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Forerunner of the Mission Complex: THE PIMA MINE STORY: Walter E. Heinrichs, Jr., 2001, Marana, Western Economic History Center, 33 p.

Walter Heinrichs, one of the mine's discoverers, describes how, for the first time, geophysical techniques were used to find a major non-ferrous ore deposit beneath more than 200 feet of cover in an area where economic mineral deposits were not believed to exist. (In 1922 the Commissioner of the General Land Office, U.S. Department of the Interior, concluded that the area within which the mine was discovered, was non-mineral in character.) Heinrichs also describes how the mine was eventually developed and subsequently incorporated into ASARCO's Mission Complex to become part of a world-class copper producer.

This full-color, illustrated, soft-cover book may be purchased from the Western Economic History Center (WEHC), P.O. Box 637, Marana, AZ 85653 (phone 520-682-4121), ASARCO Mineral Discovery Center, Arizona Historical Society, and other retail outlets.The sale price is $9.30, plus sales tax for Arizona residents, and shipping and handling. Call the WEHC for more information.

NEW COMMISSIONER

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Governor Jane Dee Hull appointed Michele Negley, of Phoenix, to serve as a member of the Arizona Oil and Gas Conservation Commission. Ms. Negley, who earned a degree in electrical engineering from Arizona State University, is Director of Energy Solutions at New West Energy, a subsidiary of Salt River Project.

NEW WEB SITE

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If you haven't already done so, please click on the newly designed web site of the Arizona Geological Survey. The site includes a description of the agency, services the agency provides, maps and reports available for purchase, and information about the geology of Arizona, including geologic maps, hazards, mineral resources, oil and gas, and much more.

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